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RESEARCH ARTICLE

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5-step approach for initiating remanufacturing (5AFIR)

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Abstract

Despite remanufacturing being a value-retention process capable of bringing both economic and environmental benefits to original equipment manufacturers (OEMs), the remanufacturing market is small, and the OEM share on the market is even smaller. There are trends in OEMs hesitating to initiate remanufacturing due to the lack of knowledge or often unjustified assumptions about how remanufacturing affects their business-as-usual. To further motivate OEMs to initiate remanufacturing, there is a need to extend the remanufacturing initiation theory to showcase how remanufacturing could be initiated in practice. Therefore, this paper aims to describe a remanufacturing initiation and demonstrate the initiation steps for OEMs by developing a remanufacturing initiation framework. The framework is developed based on a remanufacturing initiation led by an OEM of robotic lawn mowers. Based on the case study, a 5-step approach for initiating remanufacturing (5AFIR) framework—the *remanufacturing sapphire*—was developed to interpret and visualise the remanufacturing approach taken at the studied OEM. The framework steps consist of the following: (1) Select a product family, (2) involve actors prone to be impacted by remanufacturing, (3) iteratively identify prerequisites and assess the system performance, (4) develop a plan and industrialise remanufacturing, and (5) refine and validate the assessment in Step 3.

KEYWORDS

circular economy, framework, industrialisation, original equipment manufacturer, remanufacturing, shift, transition, value-retention

1 | INTRODUCTION

Resource-efficient and effective solutions are key when aiming to reduce the negative impact of humans on the climate and environment (Intergovernmental Panel on Climate Change [IPCC], 2021). One such solution is remanufacturing through its resource-use-extending capabilities throughout the product life cycle (Nasr & Russell, 2018).

Abbreviations: 5AFIR, 5-step approach for initiating remanufacturing; OEM, original equipment manufacturer; PaaS, product-as-a-service.

Remanufacturing is an industrial process that restores cores (e.g., used, discarded, or broken products) to like-new condition (Lund, 1984). The process enables a set of environmental benefits in comparison to the manufacturing of new products, for example, reduced consumption of raw materials and energy (Sundin & Lee, 2011). Through these environmental benefits, together with positive economic effects, remanufacturing establishes a vital position in a circular economy (Geissdoerfer et al., 2017; Nasr & Russell, 2018).

However, the market of remanufacturing is small, with a remanmanufacturing ratio of 1 to 50 (Parker et al., 2015; United States

International Trade Commission [USITC], 2012), especially when viewing remanufacturing activities of original equipment manufacturers (OEMs) (Lund, 2012). As such, the potential benefits of remanufacturing are not fully grasped. The perspective of OEMs is interesting to study since they have a position of great influence. Typically, OEMs possess the capability to design products for remanufacturing (Hatcher et al., 2013), and customers prefer OEM remanufacturing offerings over third-party (Subramanian & Subramanyam, 2012). Moreover, OEMs tend to get involved in remanufacturing for reasons of improved competitiveness (Allwood et al., 2011), and since product cannibalisation often is a nonissue in remanufacturing (Atasu et al., 2010), many OEMs would, therefore, economically benefit from initiating remanufacturing. However, to take a step towards an initiation, assessment methods need to be applied to judge whether remanufacturing could be a successful business opportunity (Goodall et al., 2014). For such OEM remanufacturing initiations, a number of prerequisites need to be satisfied to facilitate the flow of materials and products (van Loon et al., 2020). Some researchers, for example, Barquet et al. (2013) and Östlin (2008), describe these flows by dividing remanufacturing into a framework called the *remanufacturing system* consisting of three parts, *core acquisition*, *remanufacturing process*, and *sales channels*. These three enable the acquisition of cores, restoration of them to like-new condition, and sales of the remanufactured products. For a company that has not performed remanufacturing previously, it is required to view these parts and develop procedures that enable remanufacturing and their integration into existing supply chain operations (Vogt Duberg, Johansson, Sundin, & Kurilova-Palisaitiene, 2020). However, the challenges remanufacturers face vary between product types and company characteristics (Lundmark et al., 2009), meaning that the journey an OEM undertakes when initiating remanufacturing likely varies between cases. For example, Mont et al. (2006) described how a baby pram OEM initiated remanufacturing by integrating a new business model into the existing supply chain. Comparably, Alamerew and Brissaud (2020) showed a transition where several electric vehicle battery stakeholders were framed into a circular economy mode with the presence of remanufacturing. These examples show two separate journeys towards initiating remanufacturing; two journeys that have case-dependent applicability and provide different types of insights. Therefore, in order to provide further insights or aids for OEMs that investigate remanufacturing initiations, further examples of how remanufacturing could be initiated are needed (cf. Bocken et al., 2016; Bressanelli et al., 2019; van Loon et al., 2022). These are needed since viewing initiation examples can provide a level of confidence that a beneficial remanufacturing initiation is possible (cf. Lee & Dry, 2006). The examples provide a point of reference from which conclusions could be drawn, and they could also inspire others to action through psychological means (Lamberton et al., 2013); *if they can, why can't we?* Therefore, the aim of this paper is to describe a remanufacturing initiation and exemplify the initiation steps for OEMs by developing a remanufacturing initiation framework.

We have studied the remanufacturing initiation of an established premium electrical and electronic equipment OEM. In this paper, the decision-making process throughout the initiation has been conceptualised. This contribution can inspire other scholars and industrial partners to initiate further remanufacturing operations. Within the initiation area, Vogt Duberg, Johansson, Sundin, and Kurilova-Palisaitiene (2020) have demonstrated remanufacturing prerequisites based on theoretical and empirical data. During the remanufacturing initiation at the case company, these prerequisites were found critical to consider when initiating remanufacturing. In the present paper, the prerequisites are built upon to describe in detail the procedure taken at the case company to initiate and industrialise remanufacturing in practice.

The structure of the paper is as follows. First, we describe the methodological approach. Thereafter, the remanufacturing initiation at the case company is introduced (Section 5), and last, the initiation is positioned in a remanufacturing initiation framework (Section 6).

2 | RESEARCH APPROACH

2.1 | Case study research

The research is built upon a single case study where the unit of analysis was the development of the remanufacturing activities and the decision-making at the OEM case company. The case study research method followed the recommended case study research steps of Yin (2018), where the study is planned, designed, and prepared before data is collected and analysed iteratively.

Since the case company had not performed remanufacturing previously, the first step was to understand its current operations to enable studying remanufacturing in its context. The data collection consisted primarily of in-person and voice-call semi-structured or unstructured interviews. The preferred interview type depended on the setting, as some interviews were meeting-like while others followed traditional interview styles. The multitude of interviews enabled an in-depth study of the remanufacturing initiation as well as validation by data triangulation as the topics were covered during many instances with different case company representatives (cf. Frey & Fontana, 1991; Voss et al., 2016).

The case study consisted of six research themes from 2019 to 2021, each with distinct research questions related to the remanufacturing initiation, as depicted in Figure 1. The studies were divided into two phases and targeted different remanufacturing maturity levels at the case company. In Phase 1, the objective of the case company was to gain preliminary insights, and, therefore, few resources at the case company were dedicated to remanufacturing. In Phase 2, the case company had an internal project team with the goal of initiating remanufacturing. Each of the six studies was positioned to provide information to the case company on how remanufacturing could be framed based on its products and company structure. Through such means, the case company gained scientific and managerial insights into how they could initiate remanufacturing. These insights were studied based on the internal decision-making at the case company.

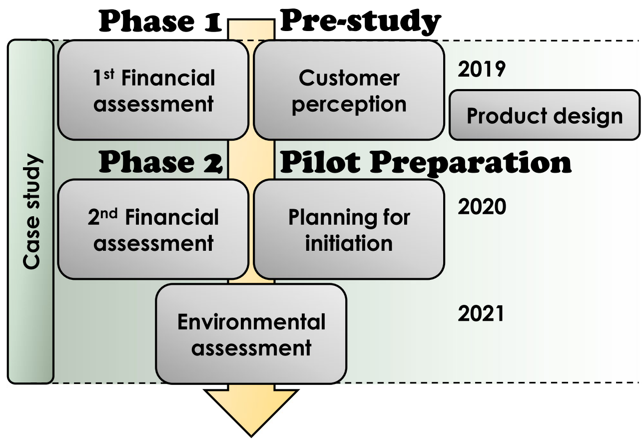

FIGURE 1 The two research phases and the six studies within the case study. See Anehagen (2021), Bergstrand and Broman (2019), Kabel et al. (2021), Vogt Duberg et al. (2021), and Vogt Duberg, Johansson, Sundin, and Tang (2020)

In total more than 100 interviews were conducted. In this paper, the progress of the remanufacturing initiation was primarily based on 88 of these interviews and 41 different case company representatives.

The collected data were thematically analysed with a basis in the remanufacturing system, see Östlin (2008), consisting of three parts: *Core acquisition*, *remanufacturing process*, and *sales channels*. Ultimately, trends in the data of the six research themes at the case company were structured to create a framework that described the remanufacturing initiation in general terms. As such, the structure of the proposed 5-step approach for initiating remanufacturing (5AFIR) framework was conceptualised and developed through the remanufacturing initiation case.

2.2 | Case company background

The studied OEM is an electrical and electronic equipment manufacturer of premium-classed robotic lawn mowers. At the start of the study, the OEM had no remanufacturing experience. The OEM acts on a global market where each market has retailers that the OEM does not control. The retailers handle most of the sales, repairs, and services of the products with support provided by the OEM. The retailers purchase products and spare parts from the OEM to maintain its approval. Through this, the OEM can influence retail practices. The retailers sell the products to the end customers, and the spare parts are either sold or used for repairs.

The primary business model used for selling the products is traditional one-off sales, where the ownership of the product is transferred at the point of sales. Therefore, the cores need to be acquired from the product owners during remanufacturing by providing an incentive.

The products are not manufactured on all markets, meaning that a logistics network has been developed to transport products between different market regions. Each market has outsourced logistics centres from which products and spare parts are distributed.

TABLE 1 The areas of investigation that were up for decision during the remanufacturing initiation at the case company. These considerations were covered to progress the project as well as to create and understand the strategy the case company should target

Areas of investigation	Main consideration
Product family selection	Initial broad focus to identify the structure of the remanufacturing system to suit several products within one product family.
Product selection and core acquisition	Specific product focus late in the planning stage. Selection criteria such as residual values, performance classeş technological obsolescence, incentive levels, availability, and customer attractiveness.
Inspection of cores	Understanding the procedure to do sufficient quality assessment from a cost perspective. Different types and number of inspections, specifying location and actors, balancing the inspection effort in terms of total cost, identifying bootleg parts, and inspection procedure.
Remanufacturing process	Creating the restoration process by defining the remanufacturing process steps and specifying a strategy such as individual core quality dependent procedures or a few overarching, centralised or decentralised remanufacturing, and component or product level focus.
Product sales	Price ratio between new and remanufactured products, impacts and expectations of product aesthetics (e.g., minor scratches), willingness to pay, variation in output between remanufacturing sites, price classes, and business model on a high level and its effect on resource flows (e.g., one-off sales or leasing).
Warranty offerings	Warranty offer difference between new and remanufactured products, managing decentralised remanufacturing with varying quality levels, tracking parts within products, legal requirements, and OEM remanufacturing certification with third-party remanufacturing.
Marketing	Efforts to persuade upper management that remanufacturing is beneficial, to collaborate with retailers, to acquire cores, and to sell remanufactured products.
Cooperation between the retailers and the case company	Establishment of collaborations or cooperations between the OEM, retailers, and other actors for core acquisition, remanufacturing, and sales. Define responsibilities and arrangement for profits on spare parts, processes, and services, as well as risk and competition analysis.

Moreover, the logistics management is planned and controlled in-house.

3 | THE REMANUFACTURING INITIATION AT THE CASE COMPANY

The case company gained an interest in remanufacturing as part of making contributions towards its sustainability vision. The three Phase 1 studies, shown in Figure 1, concluded that remanufacturing was viable at the case company considering the design of the targeted products, customer perception, and expected return on investment (Kurilova-Palisaitiene et al., 2020). These positive results enabled a prolongation of the remanufacturing project as the upper management had sufficient material indicating further positive outcomes.

At the start of the Phase 2 pilot preparation, a plan was created listing the prerequisites of initiating remanufacturing based on the current knowledge at the case company. To follow the plan, several ambiguities had to be investigated, namely, which product(s) to remanufacture, how the cores were to be acquired and inspected, how the technical process of remanufacturing should be framed, and further, which sales channels and business models to use for the remanufactured products, for example, product sales through retailers or online channels, and whether to retain the ownership of the products by selling products through leasing contracts or Product-as-a-Service (PaaS). Additionally, aspects related to after-sales activities were covered, such as services, repairs, marketing, product support, and related offerings directed to the product users. All these areas of investigation are covered in Table 1.

4 | THE 5AFIR

With a basis in the insights from the six studies with various research methods and the decision-making procedure studied at the case company (Kurilova-Palisaitiene et al., 2020), a remanufacturing initiation framework was developed: One to guide OEMs in framing the steps to systematically initiate remanufacturing.

The decision-making procedures of the remanufacturing initiation at the case company indicate that the timeline from start to finish was not straightforward. The findings also indicate that many of the challenges of remanufacturing are handled more as a single integrated unit than one step at a time. As such, many of the initiation steps are conducted in parallel, or iteratively, to build insights into how to proceed with remanufacturing. One interpretation is that one stage influences another and, therefore, they cannot be viewed as independent entities. For example, by determining the procedures of a single remanufacturing activity, such as core acquisition, independently of other activities, the case study showed that the case company would have been required to redo much of the work at a later stage due to incompatibility with other activities and demands of other departments or areas of responsibilities. Hence, to prevent overspending time resources on initiations, the framework has been designed to approach the remanufacturing initiation as a system that integrates all remanufacturing activities systematically when advancing the understanding. Such a systematic integrative approach also enables the required assessments for decision-making to stay on a low-complexity level by iteratively conducting them as new decisions are taken.

However, it might not be easy for a company to follow a set of general predetermined steps due to company-specific challenges and circumstances (cf. Lundmark et al., 2009). This difficulty is further heightened by considering a company's drivers for initiating remanufacturing, for example, for higher profitability or achieving environmental goals (Östlin et al., 2008) since the steps might not emerge from the same company values and visions. Therefore, when creating a remanufacturing initiation framework to stepwise propose how a remanufacturing initiation could be performed for OEMs, we focus on a high level to reach high applicability. The proposed framework is 5AFIR; see Figure 2. It alludes to the Scandinavian word for sapphire and positions remanufacturing as a precious, value-retention process. The framework steps are described in the subsequent subsections with reliance on the decision-making process when initiating remanufacturing at the case company.

4.1 | Step 1—Select a product family

At the case company, it was seen as a prerequisite to have selected products before specifying the exact execution of the remanufacturing process steps and planning the external processes, such as core

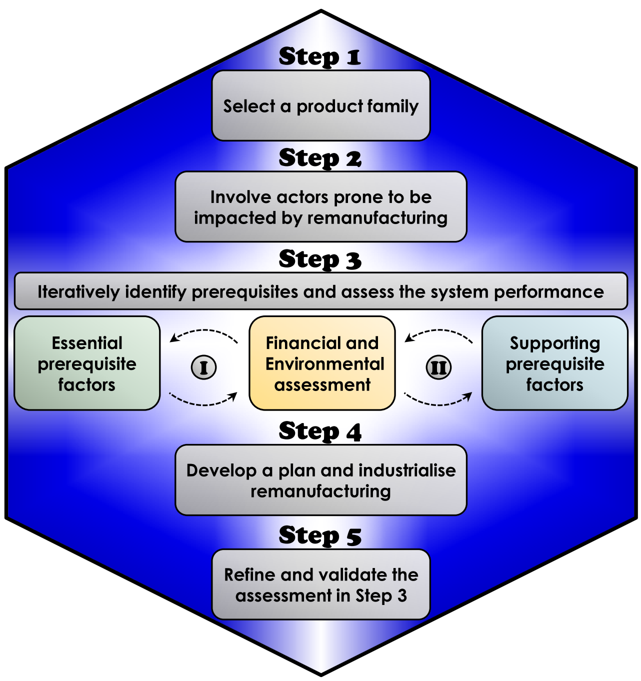

FIGURE 2 The remanufacturing sapphire consisting of a 5-step approach for initiating remanufacturing (5AFIR), which OEMs can apply when viewing their prospects of establishing an economically and environmentally beneficial remanufacturing process

acquisition and sales, according to the remanufacturing system by Barquet et al. (2013) and Östlin (2008). However, it was not considered a prerequisite to select a specific product before starting to develop the remanufacturing system.

In the framework, the fundamental step is to target a product. While the product selection process is of high importance, the given circumstances at an OEM determine how early on a specific product needs to be selected. The proposed approach here is to first focus on products from a high level by targeting a product family instead of a specific product. This is motivated by providing the opportunity to select a product based on the suitability of the remanufacturing system, that is, applying knowledge that might not be available at the early stages of the initiation. Furthermore, some activities, for example, core acquisition at the case company, were not affected by the selection of a product within the product family since the same logistics chain and procedures would be used, thus not motivating an early product selection. This is valid for the other areas of investigation (Table 1) as well, such as the *inspection of cores*, *technical remanufacturing process*, and *product sales*, thus further emphasising a late specific product selection.

While selecting a product is required before industrialising the remanufacturing system, the case study indicated that it is not necessary to select a specific product to remanufacture at the start of an initiation. Instead, a product family selection is sufficient, the reason being given that products within a product family with similar configurations, such as a common product platform (Meyer & Lehnerd, 1997), many considerations can be assessed without determining a specific product. With such an approach, it is possible to identify which product within the product family is most suitable for remanufacturing, as well as to create a remanufacturing system that facilitates multiple products. Even though developing systems for product families instead of one product can be more costly and time-consuming, the long-term financial benefits are advantageous (Jiao et al., 2007). With such reasonings, a remanufacturing system designed for a product family is more capable of handling variations and, thus, more flexible.

Furthermore, since remanufacturing is impeded by variability in core condition and quantity (Sakao & Sundin, 2019) and technological obsolescence (Seitz & Peattie, 2004; Zhou & Gupta, 2019), focusing on designing the remanufacturing system for a product family instead of a product would make the system more resilient and flexible to handle many types of cores. Therefore, it is more beneficial to first select a product family to focus on. Further down the line, a specific product could be selected to handle product-specific requirements.

By following this approach, the case company could reach an understanding of remanufacturing and thereby better understand which products are most suited to focus on first.

4.1.1 | Case company product selection

The product selection considerations at a later stage in the initiation were based on historical sales volumes, the value of the products, and the technical modernity of the product. The former was important from the perspective that high volumes would allow easy access to many cores and that it was expected that remanufactured products would inherit the market demand of their predecessor. This has been confirmed by studies on product cannibalisation (e.g., Atasu et al., 2010; Guide & Li, 2010). The residual value of the products, estimated based on historical sales prices, was also considered a factor that ensured that there was value to retain and refine during remanufacturing to achieve a profitable process.

Moreover, low-priced products were perceived as unsuitable for remanufacturing, at least when the remanufacturing system is immature, since the profitability is limited by the product's original value and would entail a deal of uncertainty due to fluctuating values having a major impact on the end results. It was, therefore, preferable to only consider products for remanufacturing whose price level enabled a lower risk-taking, meaning that any unexpected variation in the estimations would have a lower effect on the resulting profitability. Products in the low-level price class also had lower capacities and occasionally lacked the latest technical features. As the cores are expected to be acquired several years after the entrance of new products in the market, it was argued by the case company that low-end products would risk being outdated and would not be sellable, that is, having reached technological obsolescence (Seitz & Peattie, 2004). Some products could be upgraded with new technical features, in line with findings by Ijomah and Danis (2012), but this would also mean an additional level of complexity, a higher complexity that was not wanted during the initial remanufacturing phases. There is also a size difference between the low-end and the premium-priced products with the latest technology, which could entail an obstacle for a homogeneous and inflexible remanufacturing process (Sakao & Sundin, 2019). Another constraint was to ensure the availability of spare parts for older product types since the lack of spare parts could hinder remanufacturing (cf. Kurilova-Palisaitiene et al., 2018).

The considerations for selecting a product could inspire other actors during similar decisions. However, since when a certain product needs to be selected to continue the remanufacturing initiation varies between OEMs, a suitable point in time is not presented in this framework. Hence, it is only proposed to first focus on a product family; then, it is up to the investigated case to decide when it is suitable to be more specific. The product selection process can be supported by other frameworks, for example, the remanufacturing suitability matrix by Steinhilper and Weiland (2015), in which technological effort, remanufacturing yield, and usage patterns are considered.

4.2 | Step 2—Involve actors prone to be impacted by remanufacturing

Once the product family has been selected for investigation, the framing of the remanufacturing system can be initiated. To be prepared and avoid setbacks, actors with expertise from all parts of the supply chain—including the OEM, retailers, and suppliers—need to be involved, at least from areas that will be impacted by the remanufacturing system. To reach an initial view of which actors to include, we

TABLE 2 Areas of expertise of the actors involved in the remanufacturing initiation at the case company, both supply chain actors at the OEM and external

Areas of expertise			
After sales	Logistics	R&D and design	Spare parts
Business control	Manufacturing	Remanufacturing	Supply chain
Business models	Pricing	Repair and service	Sustainability
Finance	Product	Retailers	Taxation

rely on the remanufacturing system, as described by Östlin (2008), which consists of the acquisition of cores, remanufacturing process, and sales of remanufactured products. In general, the remanufacturing process can be divided into seven generic internal processes: *Cleaning*, *inspection*, *disassembly*, *storage*, *reprocessing*, *reassembly*, and *testing* (Sundin, 2004). The remanufacturing system also extends to areas such as *design for remanufacturing*, *information flows*, and *knowledge and skill of employees* (Barquet et al., 2013). All these areas should be considered in an integrated manner, and actors with expertise in each area should be involved. In Table 2, the areas covered in the case study are displayed.

To reach a systems view of remanufacturing, the involvement of all actors impacted by the remanufacturing decisions is advocated to integrate the remanufacturing system as part of the already existing activities of the OEM. This view also enables achieving a positive contribution to the circular economy (Kara et al., 2022), and there are also multiple benefits resulting from the systemic procedures. For example, it enables inputs from areas that normally do not collaborate extensively and, therefore, do not understand the impact of someone else's area of responsibility. This lack of awareness is common in remanufacturing companies (Lindkvist Haziri et al., 2019). For example, if the logistics system for remanufacturing is developed without insights into the logistics system for manufacturing, reaching synergy effects between the two systems seem unlikely. Hence, the logistics system would be ineffective in terms of costs and could potentially lead to unnecessarily disturbing existing operations. This example is quite simplified but highlighted here is the importance of properly integrating remanufacturing into the existing operations and supply chain when OEMs initiate remanufacturing, as it prevents spending resources in vain or reaching suboptimal solutions.

A central aspect of the case company's remanufacturing initiation was to determine the collaborative relationship with its retail network. Since, in this case, the retail network had the primary position to act as the middleman between the case company and the customers, it could be devastating for the OEM if a proper collaboration was not established. The different viewpoints could result in an unwillingness to continue collaborating, resulting in plummeting sales of new products, the inability to acquire cores, or diminishing customer relationships. Similarly, internal collaborations between different departments or responsibilities are of importance to prevent inefficiencies or incompatibilities, which could have been prevented if remanufacturing had been developed with all impacted areas from the beginning.

Once the potential actors have been identified, the work to collect data and insights on how to integrate remanufacturing can start. Thereafter, the requirements can be framed for specific circumstances, and the performance of the remanufacturing system can be assessed; see Step 3.

4.3 | Step 3—Iteratively identify prerequisites and assess the system performance

To frame the remanufacturing initiation, a foundation in the remanufacturing system, as defined by Barquet et al. (2013) and Östlin (2008), is set. In addition, the remanufacturing prerequisites (Vogt Duberg, Johansson, Sundin, & Kurilova-Palisaitiene, 2020) are added as a layer above to display focus areas during the remanufacturing initiation. These prerequisites were defined using the same case company in this paper and, therefore, are applied and fit well in the 5AFIR framework. The framework is used to map prerequisites during the remanufacturing initiation and consists of two categories: *Essential* and *supporting prerequisites*. The former are are fundamental requirements to create a remanufactured product from a core, while the latter enhance the performance of the remanufacturing system and potentially lead to improved benefits.

There are four essential prerequisites as follows. In summary, to initiate remanufacturing, (1) the technological requirements of the process must be satisfied (*remanufacturing process and technology*). As such, the development of all remanufacturing process steps—cleaning, inspection, disassembly, storage, reprocessing, reassembly, and testing (Sundin, 2004)—and related technologies and equipment are required to transform cores into remanufactured products. However, since cores are critical inputs to the process, remanufacturing cannot be initiated without them. Therefore, the (2) core acquisition and reverse logistics prerequisite covers how cores of a sufficient condition can be acquired and, through reverse logistics, relocated from the user to the remanufacturing facility (*core acquisition and reverse logistics*). The (3) industrial process must be facilitated near both the logistics network and the workers but also support sufficient throughput rates (*remanufacturing facilities*). In the remanufacturing facilities prerequisite, there are also considerations of centralised remanufacturing (e.g., a single location adjacent to manufacturing) or decentralised (e.g., multiple workshops distributed on the market) and their influence on the capacity and capability of the remanufacturing facility. At the facility, (4) the presence of skilled workers is required to reprocess these cores to like-new condition, given that the remanufacturing process tends to be labour-intensive to handle the variation in the condition of cores (*labour skill and availability*). The workers also need to be highly skilled and flexible to adapt their procedures given the conditions of the acquired cores (Guide & Van Wassenhove, 2001; Sakao & Sundin, 2019). Therefore, suitable workers must not only be identified; procedures to train them must also be developed. Without these four prerequisites, the remanufacturing system risks failing.

Additionally, the supporting prerequisites focus on improvements, information flows, information dissemination, and various types of planning and control. For example, for the remanufacturing system to be effective long-term, it is required to manage changes and plan on an (5) organisational level at the OEM (*organisation, planning, and control*). The remanufacturing system, its resource flows, and operations should be integrated into business-as-usual to reach synergies and manage all steps from cores and additional resource inputs to the remanufactured products. It is also of interest to (6) position the remanufactured products on the market to stay competitive (*remanufacturing market knowledge*). Here, the OEM benefits from understanding the market, and the remanufacturing system should be adapted to enable a product offer that is demanded. As part of this, the (7) remanufacturing process must not only work but also provide competitive levels of outputs (*remanufacturing process improvements*). To achieve such outputs, efficiency strategies, such as lean remanufacturing (Kurilova-Palisaitiene et al., 2018) or other efficiency philosophies (Guide, 2000; Junior & Filho, 2012), can be applied. The remanufacturing system is also dependent on (8) well-designed information flows due to the complexity and variation of remanufacturing (*design for remanufacturing and information feedback*). Therefore, to secure access to the right information at the right time, the remanufacturing system should be designed to enable such flows. Additionally, information feedback channels are to be integrated into common practice to provide a link of communication between research, development, and design departments to remanufacturing. Together, these lead to improved management and profitability of the remanufacturing system. For further details of how the prerequisites are defined, see Vogt Duberg, Johansson, Sundin, and Kurilova-Palisaitiene (2020).

Using these prerequisites, a company can build a plan for remanufacturing or a model to use when assessing remanufacturing. In the case study here, the primary request by the case company was to rely on financial assessments to motivate the remanufacturing initiation. Therefore, the environmental assessment was performed late in the study, as seen in Figure 1. However, financial and environmental assessments could be performed in parallel throughout an initiation; see, for example, Alkhayyal (2019) and van Loon and Van Wassenhove (2018). In the proposed 5AFIR framework, the system assessment includes both a financial and environmental assessment to support the development of the remanufacturing system. Procedures for such assessments can be viewed in, for example, Butzer et al. (2017), Goodall et al. (2014), Kanzari et al. (2022), Kurilova-Palisaitiene (2021), Low and Ng (2018), Peters (2016), and Rizova et al. (2020).

Proposed here is that the inputs to the system assessment should be added separately for the essential and supporting prerequisites. First, as shown in Step 3 in Figure 2, the essential prerequisites are framed at the company level. These framings are inserted into a system assessment, which provides preliminary results of how well the remanufacturing system performs. By using the assessment results, indications can be given of what does not perform according to expectations, which allows for refinements of the remanufacturing system framing. The process should then go back and forth between framing the essential prerequisites and the system assessment until a steady state has been reached. In the presented case description, it is primarily this iterative process that influences the different stages of decision-making.

Second, the supporting prerequisites are applied when framing the industrialisation of the remanufacturing system. These are added later since they are not essential for remanufacturing to operate but required for high profitability. The iterative assessment with the essential and supporting prerequisites is motivated in terms of complexity. Directly adding all prerequisites would increase the complexity of the system assessments as there would be many connections with unclear relations, thus hindering the comprehension of the remanufacturing system. As such, the supporting prerequisites are integrated into the framing of the remanufacturing system by iteratively performing the system assessment and refining the prerequisites.

In the case study, the financial prospects were continuously assessed and provided additional insights as data availability increased and decisions were taken. In that regard, the assessments influenced the design of the remanufacturing system to be more economically effective. The assessments covered aspects such as product selection, inspection procedures, remanufacturing locations, logistics solutions, product quality outputs, and the remanufacturing process steps. By utilising the approach, the case company could progressively target areas of the remanufacturing system to create well-informed decisions without creating an overwhelming complexity.

Once the ideation of the remanufacturing system has been framed and assessed, a plan for how to initiate and industrialise remanufacturing in practice can be derived. This is further described in Step 4.

4.4 | Step 4—Develop a plan and industrialise remanufacturing

Up to this point, the described remanufacturing initiation procedure has been on a design and assessment level without any practical industrialisation of the remanufacturing system. The plan considered in this step is the industrialisation of the remanufacturing system.

At the case study company, the industrialisation plan was all considerations and decisions taken. In the study, remanufacturing was planned to be performed in a decentralised manner where all logistics solutions and equipment for remanufacturing could be covered by existing practices. Therefore, the threshold to go from the ideate phase of the remanufacturing system to industrialisation was low. It mostly consisted of setting guidelines for remanufacturing for relevant actors to follow. There was also a plan for centralised remanufacturing, but these practices were not finalised as the progress from a pilot study, where remanufacturing is industrialised on a small scale, was considered valuable input for future development.

During other circumstances, the plan for industrialising a remanufacturing initiation can be demanding, which signifies the importance of this step (Step 4). For example, developing the technology to reprocess cores or other internal remanufacturing steps could be required to restore cores to like-new condition. Other examples are the development of remanufacturing production systems (Grubbström & Tang, 2006; Junior & Filho, 2012) or the creation of reverse logistics networks (Chiarini, 2014; Tombido & Baihaqi, 2022; Wei et al., 2015). Depending on what present operations are at the initiating OEM to be utilised for remanufacturing short- or long-term, the investment cost and the complexity are influenced.

As Step 2 involved all actors impacted by remanufacturing and Step 3 provided assessments of the planning stage, the initiation in practice has been prepared to be as free of hindrances as possible from an acceptance point of view. Since all supply chain actors have influenced the plan and are aware of the financial and environmental effects, they are aware of why remanufacturing is initiated and how it affects them. This awareness is important in circularity transitions as inertia towards changes is often present at different management levels (Yamoah et al., 2022): inertia that must be overcome to transition from planning to industrialisation.

4.5 | Step 5—Refine and validate the assessment in Step 3

The last step of the 5AFIR framework is used for reflection, that is, to embrace the lessons learned from the remanufacturing initiation. No matter how thorough the planning was and accurate the assessments were, there are likely to be deviations when comparing measurements of the expected and the industrialised remanufacturing system. By assessing and comparing the planned and expected state with the real state, the OEM can refine the models used and the insights utilised when targeting further cases of remanufacturing, such as other product families or products within a product family.

At the case company, a small-scale industrialisation pilot of remanufacturing was part of validating the planned and assessed remanufacturing system. The pilot was used to further understand whether remanufacturing was worth scaling up and how the remanufacturing system could be improved. Such pilots are also important for refining the planning and the assessment methods of the prior initiation steps for further iterations of remanufacturing initiations.

The refinement and validation can also contribute to new remanufacturing insights. For example, by applying a mindset of continuous improvement (Blomsma et al., 2022; Pettersen, 2009), the initiated and industrialised remanufacturing system can be improved, and through this step (Step 5) the refined models and insights can be applied to judge the reasonability of the improvements of the remanufacturing initiation steps.

5 | DISCUSSION AND CONCLUSIONS

The research in this paper is built upon the initiation of remanufacturing of an electrical and electronic equipment OEM. The OEM was studied from 2019 to 2021 during its initiation of remanufacturing. At the start of the study, the OEM had no remanufacturing experience, but in the end, it was ready to run a small-scale industrialisation pilot of remanufacturing. This remanufacturing initiation has been studied from a decision-making perspective where the insights from the case company have been enclosed in a wide range of areas linked to remanufacturing. These remanufacturing initiation insights are the primary novelty of this research since they are needed to provide other OEMs perspectives on how to initiate remanufacturing.

Based on the remanufacturing initiation at the case company, scientific literature, and previous research, 5AFIR was developed. The framework translates the described initiation into more general terms to show the underlying approach and describe a systemic way to initiate remanufacturing. Metaphorically, the 5AFIR specifies a path with clearly defined boundaries leading up to a remanufacturing initiation. The framework shows the trend in the remanufacturing initiation of the provided case description, a trend that other remanufacturing initiations are proposed to follow.

The designed iterative nature of the framework is based on mapping the prerequisites in order of priority, where first, the essential prerequisites are investigated and assessed to create the basis of the remanufacturing system without focusing on efficiency measures. Thereafter, supporting prerequisites are integrated and assessed. Through this approach, the case company could plot the remanufacturing system by focusing on the remanufacturing process and see whether or how it works before polishing it to a competitive standard. For example, if the remanufacturing process is designed to handle cores of low variability and high throughput rates, the remanufacturing system must be configured to filter out low-quality cores as well as have logistics and sales solutions available to support the quality and volume requirements. This focus was beneficial as a preliminary remanufacturing plan could be communicated through various instances at the OEM early on and before a complete solution had been developed. This enabled further involvement of supply chain actors and provided an acceptance for remanufacturing and an opportunity for them to influence.

By presenting the iterative framework that 5AFIR consists of, an addition to the body of knowledge within evaluation methods for value-retention processes is made. In the area of sustainability, especially circularity, extensive academic work has been conducted in creating frameworks (Centobelli et al., 2020; Geissdoerfer et al., 2017; Ghisellini et al., 2016; Kalmykova et al., 2018). Examples of such work are the development of circularity maturity stages, ranging from screening suitable circular procedures (Blomsma et al., 2019) to configuring a circular system (Pieroni et al., 2019, 2020). By applying such models in practise at various stages, enhanced sustainability performance at companies could be achieved. Moreover, many of these methods cover remanufacturing as part of the solution to achieve a sustainable society. Examples of such contributions are the prioritisation of circularity strategies (Kirchherr et al., 2017; Potting et al., 2017) and conceptualisations of the circular economy (Ellen MacArthur Foundation [EMF], 2015; Geissdoerfer et al., 2017; Suchek et al., 2021). Within these frameworks, the scope varies, such as on the business model innovation to enable circular practice (Bocken et al., 2016; Linder & Williander, 2017) or the focus on design and efficiency measures as well as a societal change from a whole-systems perspective to enable a circular transformation (Kara et al., 2022). Evidently, there are various ways of approaching circularity. By proposing the 5AFIR framework, we target circularity through remanufacturing specifically. Instead of focusing on multicriteria decision-support frameworks (Nasr & Russell, 2018; Subramoniam et al., 2013; Yang et al., 2016) or efficiency measures (Goodall et al., 2014; Junior & Filho, 2012; Rizova et al., 2020), the 5AFIR framework attempts to fill the gap of models which promote remanufacturing initiations. Its high-level focus provides a wide view of the remanufacturing prospects while concurrently providing the flexibility to integrate various assessment models for economic and environmental performance, depending on drivers and characteristics. Similar to the remanufacturing readiness level tool Remometer (Kurilova-Palisaitiene, 2021), the 5AFIR framework is niched towards aiding companies in understanding whether remanufacturing is worth focusing on. In contrast to broader circularity frameworks, it neglects the trade-off between various value-retention processes (Nasr & Russell, 2018). Instead, the provided deeper understanding of remanufacturing could prepare for new types of knowledge-building within OEMs.

With support not only from the remanufacturing initiation case and the six underlying studies (see Figure 1) but also through the remanufacturing prerequisites (Vogt Duberg, Johansson, Sundin, & Kurilova-Palisaitiene, 2020), the 5AFIR framework contributes to a visualisation of how a remanufacturing initiation could be achieved as well as advances the knowledge of structuring remanufacturing assessment methods.

With the remanufacturing initiation case and framework, insights are provided into how primarily similar companies to the case OEM can frame their plans to initiate remanufacturing.

6 | FUTURE RESEARCH

With the research contribution presented here, we would like to aid both industry partners and academic scholars in understanding how remanufacturing can be initiated at OEMs. We did this by studying an OEM of premium electrical and electronic equipment. However, since company and product characteristics vary from case to case, this study is one example that might fit a limited number of companies. Therefore, the call for future research, as linked to this paper, is to provide further descriptions of how different types of companies have initiated remanufacturing.

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